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(54) Manufacture of a solid urea-formaldehyde resin

(57) A process for the manufacture of a solid urea-formaldehyde resin comprises the steps of

(a) reacting a solution of formaldehyde in water with urea under acid conditions at a molar ratio of formaldehyde to urea which is greater than 2.5 to 1 the reaction conditions being 15 to 100 minutes at 100°C at pH6 or their equivalent, adjusting the pH to be neutral to mildly alkaline and

(b) if necessary concentrating the solution so made to reduce its water content to less than 50 per cent by weight

(c) adding further urea to adjust the molar ratio of formaldehyde to urea to between 2.0 to 1 and 1.1 to 1, and

(d) evaporating water from the solution under conditions whereby rapid evaporation of water takes place without substantial increase in the degree of condensation of the resin and without substantial precipitation of the solid resin to reduce the water content to such a level that on cooling the liquid resin product a friable solid is obtained.

Step (d) may be carried out using a thin film evaporator or a vacuum kneader or by spray drying. The degree of condensation of the solid resin produced may range from 25 to 50%.

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SPECIFICATION

Improvements in or relating to resin manufacture

- 5 This invention relates to the manufacture of resins and in particular to the manufacture of resins from urea and formaldehyde. 5

In our UK published application No 2155941A we have described and claimed a process for the manufacture of a solid urea-formaldehyde resin which comprises the steps of

- (a) reacting a solution of formaldehyde in water with urea at a molar ratio of formaldehyde to urea which is greater THAN 2.5:1, 10 10

(b) concentrating the solution so made until its total water content was less than 50% by weight.

(c) adding further urea to adjust the molar ratio of formaldehyde to urea to between 2.0:1 and 1.1:1 and

- (d) concentrating the solution further without precipitation of solid resin to reduce the water content to such a level that on cooling the liquid resin product, a friable solid is obtained, wherein a stabilization agent is reacted into said solution of formaldehyde or formaldehyde and urea prior to step (d) in order to prevent precipitation of resin in step (d). 15

- This process is suited to batch manufacture of resin using bulk evaporation in step (d) and uses a stabilization agent which is reacted into the resin prior to step (d). 20 20

The process can be used to make solid resin if step (d) is carried out in other ways but we have also found that if the other steps are carried out in particular ways, and step (d) is carried out rapidly, for example in a vacuum kneader or on a thin film evaporator, the stabilization agent need not be used.

- 25 Thus according to the present invention a process for the manufacture of a solid urea-formaldehyde resin comprises the steps of 25

(a) reacting a solution of formaldehyde in water with urea under acid conditions at a molar ratio of formaldehyde to urea which is greater than 2.5 to 1 the reaction conditions being 15 to 100 minutes at 100°C at pH6 or their equivalent, adjusting the pH to be neutral to mildly alkaline 30 30

(b) if necessary concentrating the solution so made to reduce its water content to less than 50 per cent by weight

(c) adding further urea to adjust the molar ratio of formaldehyde to urea to between 2.0 to 1 and 1.1 to 1, and

- (d) evaporating water from the solution under conditions whereby rapid evaporation of water takes place without substantial increase in the degree of condensation of the resin and without substantial precipitation of the solid resin to reduce the water content to such a level that on cooling the liquid resin product a friable solid is obtained. 35 35

- The first step of the process is reaction of urea and formaldehyde under acid conditions. It will be appreciated that the higher the temperature the greater is the rate of reaction and lowering the pH of the solution has the same effect. By "equivalent conditions" we mean conditions of temperature/time/pH which will give rise to the same degree of condensation in the reaction product. 40 40

Degree of condensation may be determined from the following formula

- 45 Degree of condensation (%) =
$$\left\{ \frac{\text{Total HCHO (1)} - \text{Methylol HCHO (2)}}{\text{Total HCHO (1)}} \right\} \times 100$$
 45

- 50 Where 50

(1) Total HCHO is the total formaldehyde content determined by acid hydrolysis followed by sulphite determination of liberated formaldehyde

(2) Methylol HCHO content is determined by the ACC Sulphite method.

- The pH is preferably adjusted when necessary during the process using such reagents as sodium hydroxide and formic acid. It is preferred not to use a mineral acid. 55 55

Since precipitation of highly condensed insoluble resin is to be avoided step (a) should be carried out in a controllable manner and temperatures above 100°C would normally not be used. Similarly a pH below 4 would normally be avoided.

- Temperatures up to 150° could be employed if the reaction were carried out under elevated pressure in a suitable vessel and appropriate modification of the pH conditions would then be required. 60 60

Alternative conditions to the 15 to 100 minutes at pH6 and 100°C can readily be determined experimentally by those skilled in the art.

- The step (b) need only include concentration if the water content at the end of step (a) is above 50 per cent by weight, but it is necessary to adjust the pH to neutral or mildly alkaline 65 65

conditions. Theoretically neutrality is the ideal, however, when urea is added in step (c) slight acidity develops and it is usual to make the solution mildly alkaline in step (b) to ensure that the urea addition does not re-create acid conditions. By "mildly alkaline" we mean having a pH of about 7.5 to 8.5.

- 5 In step (c) care must be taken to make sure that the molar ratio of formaldehyde to urea does not fall below 1 to 1 at any stage. 5

The step (d) will generally be carried out using a thin film evaporator or a vacuum kneader or a spray dryer may be used. These create conditions wherein water can be removed very rapidly thereby enabling concentration to take place without substantial further condensation of the resin. Spray drying is a less convenient method because of the relatively low melting point of the resin being made, and this would require special provision to cool and collect the dried but tacky resin particles. 10

All the various types of thin film evaporator may be used including, for example, roller driers, and enclosed evaporators in which the thin film is on the interior surface of a heated drum. The latter includes wiped film evaporators. 15

The total water content of the solid resin product produced after cooling is in the range 5% to 12% and the resin is readily soluble in hot water. Preferably the degree of condensation of the solid resin is in the range 25 to 50 per cent, more preferably 35 to 45 per cent.

It will be noted that the process described in the present invention can give a satisfactory solid resin product at a degree of condensation slightly higher than the 25 per cent to 45 per cent claimed in UK Published Application 2155941A. 20

Thus the present invention provides also a resin comprising a reaction product of urea and formaldehyde having a molar ratio of formaldehyde to urea which is between 2.0 to 1 and 1.1 to 1 and wherein the degree of condensation of the resin is greater than 45 per cent but not greater than 50 per cent and the resin is solid at room temperature. 25

Resin Modifiers may be introduced into the resin at any stage of the reaction for benefits they may give during manufacture of the resin, eg to enable particular degrees of condensation to be achieved, or during subsequent uses of the solid resin. Modifiers which can be used include, for example, "amides, reactive organic hydroxyl compounds, amino triazine compounds such as melamine, and the reaction products of these compounds with formaldehyde. Examples of specific compounds which can be used are acetamide, sulphanilamide, malonamide, para-toluene sulphonamide, succinamide, dicyandiamide, phenol, ethylene glycol, o-cresol and melamine-formaldehyde resins. Mixtures of modifiers may also be used. Preferred modifiers are melamine, p-toluene sulphonamide and sulphanilamide. 30

The amount of such modifier when used in this way is preferably not more than 10% by weight of the total resin. There is no theoretical minimum but in general at least 1% by weight would normally be used to gain the desired benefits in subsequent performance when using the resin. 35

If it is desired to produce a mixed resin, greater amounts of the modifier compounds may be incorporated for example up to 30% by weight of the resin. Melamine is particularly suitable to be used in this way. 40

The resin may be used for example in the manufacture of laminates or adhesives or as the solid resin in the amino formaldehyde compositions described in our UK Published Application No 2158082A.

45 The invention will now be particularly described, by way of example only, by means of the following examples. 45

Examples

(a) Preparation of resin solution (Steps A to C)

50 In all of the preparations of the solutions the following formulation was used: 200 litres 44% Formalin, 66 kg urea 50

This was reacted under acid conditions pH 5.8-6.0 for 15, 60 and 90 minutes. At this point the pH was adjusted to 7.8-8.0, and the distillate removed was weighed. If less than 74 kgs had been removed, which was the case in both the 15, and 60 minute preparations, vacuum concentration was carried out at 65°C until the required amount of distillate had been removed. 55

In the 90 minute acid phase preparation more than 74 kg of distillate was removed, therefore the difference was returned to the still and no vacuum concentration was required.

63 kg urea with PTSA and Melamine to give 1.8% and 1% in the resin was added to the 15 and 60 minute acid phase resin solutions and dissolved before discharging. In the case of the 60 90 minute acid phase resin 63 kg of urea was added and dissolved but only half was discharged initially. To the other half were added 1.8% PTSA* and 1% Melamine as modifiers and dissolved before the resin solution was discharged. 60

(*PTSA is p-toluene sulphonamide)

65 (b) Evaporation of resin solution (step d) 65

The resin solutions so prepared were fed to a thin film evaporator for water to be removed for step (d). The evaporator used had a steam heated drum 155mm in diameter and 2.5 sq.ft. of evaporation surface.

The steam pressures rotor speed, feed rate etc were successfully adjusted in order to produce a brittle resin in each case and details of the process conditions are given in table 1 over the page.

TABLE 1

Example No	1	2	3	4
Resin	15 Min acid phase (Modified)	60 Min acid phase (Modified)	90 Min acid phase (Modified)	90 Min acid phase (Unmodified)
Steam Pressure (psi)	80	80	75	80
Rotor Speed (rpm)	370	370	290	290
Product Temp. (°C)	125	125	125	123
Feed Rate (Kg/hr)	32	41	—	—
Comments	one resin sample precipitated	satisfactory	Resins tended to exotherm in cooling tray	

The composition and properties of the solid resins produced are given below in Table II.

TABLE II

Example No	1	2	3	4
Urea:				
Formaldehyde molar ratio	1:1.43	1:1.43	1:1.42	1:1.42
Total H ₂ O content (%)	11.4	11.9	10.7	11.5
Free H ₂ O content (%)	1.7	1.6	2.4	2.09
Degree of Condensation (%)	34.5	40.0	48.7	41.4
Melting Point(°C)	89	60	75	73

The examples clearly establish that satisfactory resins may be produced using the process as described, and a thin film evaporator.

The resins produced with 15 minute acid treatment showed some signs of instability, one precipitating unexpectedly and it was concluded that the 15 minute treatment is the borderline for stable resin.

The 60 minute resin was satisfactory in every way. The 90 minute resins produced were satisfactory but the tendency to exotherm when discharged from the evaporator showed signs of impending difficulty. An attempt to produce a resin using a 120 minute acid reaction phase totally failed, the resin overheating and gelling during water removal.

CLAIMS

1. A process for the manufacture of a solid urea-formaldehyde resin which comprises the steps of

(a) reacting a solution of formaldehyde in water with urea under acid conditions at a molar ratio of formaldehyde to urea which is greater than 2.5 to 1 the reaction conditions being 15 to 100 minutes at 100°C at pH6 or their equivalent, adjusting the pH to be neutral to mildly alkaline and

(b) if necessary concentrating the solution so made to reduce its water content to less than 50 per cent by weight

(c) adding further urea to adjust the molar ratio of formaldehyde to urea to between 2.0 to 1

and 1.1 to 1, and

(d) evaporating water from the solution under conditions whereby rapid evaporation of water takes place without substantial increase in the degree of condensation of the resin and without substantial precipitation of the solid resin to reduce the water content to such a level that on cooling the liquid resin product a friable solid is obtained.

2. A process according to Claim 1 in which step (a) is not carried out under pressure and is carried out at a temperature not greater than 100°C and a pH in the range 4 to 6.

3. A process according to Claim 1 or 2 in which step (d) is carried out using a thin film evaporator or a vacuum kneader.

4. A process according to Claim 1 or 2 in which step (d) is carried out by spray drying.

5. A process according to any preceding Claim in which a modifier compound is incorporated into the resin at any stage of the reaction.

6. A process according to Claim 5 in which the modifier compound is incorporated in an amount up to 30 per cent by weight of the resin.

7. A process according to Claim 5 in which the modifier is selected from amides, reactive organic hydroxyl compounds, amino triazine compounds, the reaction products of such compounds with formaldehyde, and mixtures thereof.

8. A process according to Claim 7 in which the modifier is selected from melamine, para-toluene sulphonamide and sulphanilamide and mixtures thereof.

9. A process according to any preceding Claim in which the degree of condensation of the solid resin is in the range of 25 per cent to 50 per cent.

10. A resin comprising a reaction product of urea and formaldehyde having a molar ratio of formaldehyde to urea which is between 2.0:1 and 1.1:1 and wherein the degree of condensation of the resin is greater than 45 per cent but not greater than 50 per cent and the resin is solid at room temperature.

11. A solid resin according to Claim 10 in which the amount of said resin modifier is in the range of 1 per cent to 10 per cent by weight of the total resin.

12. A solid resin according to Claim 10 which is a mixed resin in which the modifier compound is incorporated in an amount up to 30 per cent by weight of the resin.

13. A solid resin according to Claim 10, 11 or 12 which contains a resin modifier selected from amides, reactive organic hydroxyl compounds, aminotriazine compounds and the reaction products of such compounds with formaldehyde, and mixtures thereof.

14. A solid resin according to Claim 13 in which the modifier is selected from acetamide, sulphanilamide, malonamide, para-toluene sulphonamide, succinamide, dicyandiamide, phenol, ethylene glycol, o-cresol and melamine and mixtures thereof.

15. A solid resin substantially as described herein in Example 3.

16. A method for the manufacture of a solid resin as claimed in Claim 1 substantially as described herein with reference to the foregoing Examples.